RECTIFIER ACTION OF A GAS DISCHARGE AND ITS DEPENDENCE ON THE V-I CHARACTERISTICS IN THE FORWARD AND THE REVERSE DIRECTION

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ABSTRACT. Observations on the rectification produced in a glow discharge in Hydrogen ($p = 94-275\mu$) do not show good correlation with the values to be expected from the $d-c$ $V-I$ characteristics in the forward and the reverse direction. It is suggested that this may arise because the electrical conduction in the two half cycles may not be independent, which has been confirmed by observations obtained with a transverse magnetic field applied at one of the electrodes.

Gaseous devices for rectification (Gnntherschulze, 1927) of low frequency a.c. are well known. They are of several types, of which the two (physically dissimilar) electrode system with a hot or a cold cathode is the most common type. The rectification produced by such a device is based on the asymmetric conductivity of the gas when the first or the second of these electrodes functions as the cathode. The effect can be explained in some cases in terms of the cathode fall at each of the electrodes i.e. to say in terms of the d.c. V-I characteristics in the forward and the reverse direction. Under these conditions the rectification should be determined by the eletrode geometry, the nature of the gas and its pressure etc. (Chiplonkar, 1939 1941). It is clear that whereas the average rectified d.c. output voltage given by the device will be also determined by the ignition potentials in the two half cycles (Talekar, 1956), (which will control the conduction angle of the current), the peak values of the current in the two half cycles will however be determined by the V-I characteristics only, if one assumes that the electrical conduction in the two half cycles can be considered to be independent of each other. For a given gas the V-I characteristic of a discharge is controlled by the gas pressure p and to a limited extent by D, the interelectrode distance. By a suitable variation of p and D, it is possible to vary the nature of the V-I characteristic so that the discharge changes from the normal, to the abnormal or to the obstructed type, as the case may be. The last type of discharge is obtained when the length of the cathode dark space $\geqslant D$. It may be mentioned that there is no theory available at present (Von Engel, 1965), which is able to account for the different V-I characteristics observed for these different types of discharges. As a matter of fact these types are specified in terms of their V-I characteristics. It is also known that the V-I characteristics of a discharge can be appreciably modified by the application of a magnetic field at a suitable point of the discharge. The object of the present investigation was to examine the correlation between the rectification observed and the corresponding d-c V-I characteristics when these are altered by varying p and /or D or by the application of a suitable magnetic field at one of the electrodes. No attempt was however made to investigate the wider problem of the effect of the magnetic field on the nature or form of the characteristic or on the other parameters of the discharge.

The discharge tube used (Pyrex glass, length = 25.0 cm. diameter = 3.0 cm.) was provided with two electrodes of Aluminium (i) A (dia = 2.9 cm.) and (ii) B (dia = 1.4 cm). The interelectrode distance D between them could be varied by a magnetic device. No gas streaming was used during the observations. The pressure of the gas in the discharge tube was measured with the help of a thermocouple gauge previously calibrated. The magnetic field was supplied by means of a permanent magnet and had a magnitude $\simeq$150 Oe as measured with a search coil The d.c. V-I characteristics with electrode (i) A as the cathode and (ii) B as the cathode were taken with the help of a d.c. power-pack (output 20 kV, 20 mA, ripple factor $<<$ 0.5 per cent). The circuit arrangement Chiplonkar (1951) shown in Fig. (1) was used, to determine the dynamic rectification. The

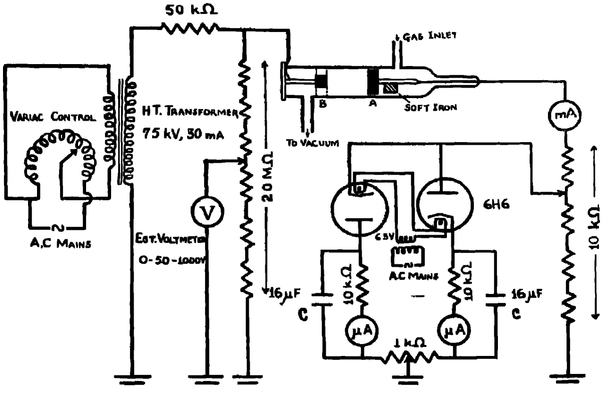

Fig 1. Discharge tube and electrical connections for measurement of rectification.

use of the condensers C enabled the direct measuremenr of the peak values of the current in the two half cycles for the a.c. operation. If $\hat{i}_+$ and $\hat{i}_-$ represent these peak values, the rectification ρ observed is taken as

$$\rho = \frac{2(\hat{i}_+ - \hat{i}_-)}{\hat{i}_+ + \hat{i}_-}$$

In terms of this notation $\rho = 2.0$ would correspond to complete rectification. The values of ρ were determined in this manner as a function of the peak value of the a.c. applied voltage $\hat{V}_{AC}$ across the tube for different p and D. The rectification ratio ρ' to be expected from the characteristics was calculated from the relation

$$\rho' = \frac{2(i_A - i_B)}{i_A + i_B}$$

where i_A and i_B represent respectively the currents observed in the d.c. V-I characteristics corresponding to $V = \hat{V}_{AC}$ when (i) A or (ii) B is used as cathode. In order to bring out clearly the dependence of ρ on the V-I characteristics, observations were also taken on both these parameters in the presence of a transverse static magnetic field when applied near the electrode A. The application of the field was found to modify the characteristics to a significant extent. One typical set of these observations with and without this magnetic field are shown in Fig (2). From the characteristics it is clear that the discharge is abnormal (with a positive slope for the V-I characteristic) except in the case of curve I for a small range of currents (0-1.5 mA) where the discharge is obstructed. Fig (3) curves

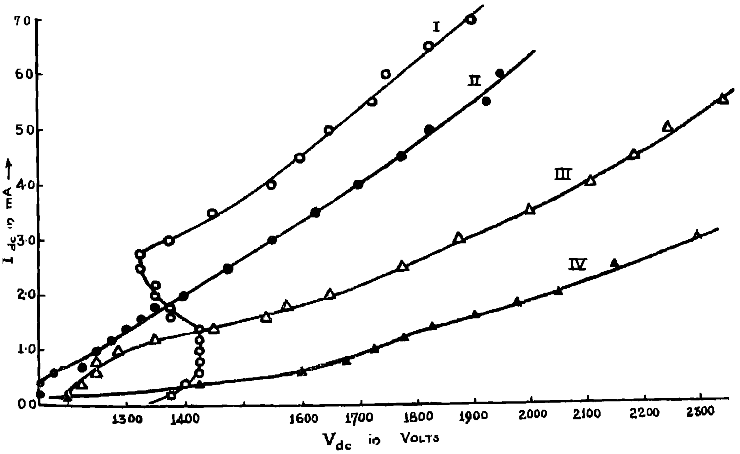

Fig. 2. d.c. V-I characteristics for discharge in hydrogen.

$p = 170$ microns, $D = 2.0$ cm.

I Electrode A as cathode (without field).

II Electrode A as cathode (with transverse magnetic field at A).

III Electrode B as cathode (without field).

IV Electrode B as cathode (with transverse magnetic field at A).

(I-V) represent the values of ρ/ρ' as a function of the peak values of the a.c. e.m.f. applied with and without the magnetic field.

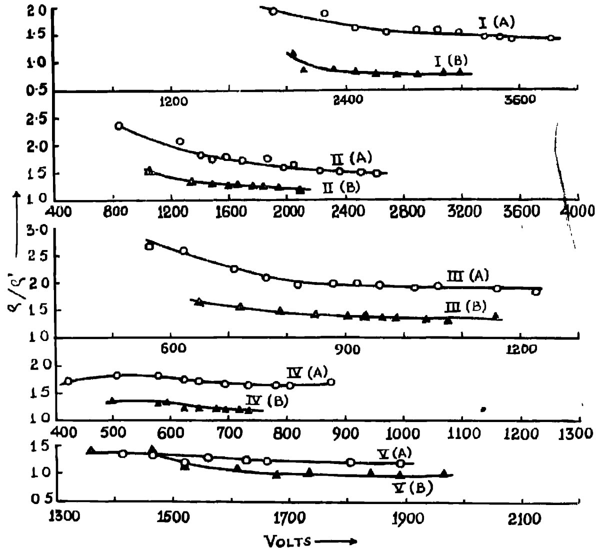

Fig. 3. Variation of ρ/ρ' with voltage.

ρ = observed rectification ratio
ρ' = calculated rectification ratio

I p = 94 microns, D = 4.0 cm.
A — without magnetic field,
B — with magnetic field.

II p = 140μ, D = 4.0 cm.
A — without magnetic field,
B — with mannetic field

III p = 210μ, D = 4.0 cm.
A — without magnetic field,
B — with magnetic field.

IV p = 275μ, D = 4.0 cm.
A — without magnetic field,
B — with magnetic field.

V p = 170μ, D = 2.0 cm.
A — without magnetic field,
B — with magnetic field.

Observations were taken for a glow discharge in hydrogen within the pressure range of 94-275μ for D, the interelectrode distance, between 2.0-4.0 cm. A few typical curves obtained are shown in Fig. 3 (I-V). The observations obtained for the case where the magnetic field is not present show values for ρ/ρ' which are very much greater than one, indicating that the actual rectification is always very much higher than the expected. The ratio shows a slow decrease with increasing voltage. The discrepancy between the magnitudes of ρ and ρ' may possibly occur because the conduction in the two half a.c. cycles may not be independent of each other as assumed in our analysis. The necessary condition to be satisfied for this to happen is that the quiescent time interval between the quenching of the current in one half cycle and its ignition in the next consecutive half cycle sh°uld be less than the deionisation time for the device. Support is given to this view by the observations obtained under the same conditions with a transverse magnetic field. One expects the magnetic field to deflect the discharge channels in the two half cycles in opposite directions and thus help to make them independent of each other. This is in fact shown by our observations that ρ and ρ' under these conditions have values which are not very much different from each other. It may be remarked that a gas rectifier with a three electrode system based on the deflection of the discharge channels in opposite directions by a transverse magnetic field has been reported (von Engel and Steenbeck, 1932)

Only in the case of the observations shown in Fig. 3-V which was obtained for an obstructed discharge, that the agreement between ρ and ρ' is fairly good even in the absence of the magnetic field. As the magnitude of the plasma region is negligible in this case, the results may be taken to indicate that the deionisation time effects of the plasma region are more important than those of the cathode dark space region.

One can therefore conclude that the dynamic rectification observed in the case of a glow discharge cannot be predicted from its d.c. V-I characteristics, a result in agreement with the observations of Sisodia (1963) for a hollow cathode discharge.

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